HOSTED BY

ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Pacific Science Review 16 (2014) 167–169

www.elsevier.com/locate/pscr

Application of a two-channel fibre-optic Mach-Zehnder interferometer for deformation measurement

Oleg T. Kamenev [a,*], Yuri S. Petrov [b], Ruslan V. Khiznyak [b], Roman V. Romashko [b]

[a] *Far-Eastern Federal University, Vladivostok, Russia*

[b] *Institute of Automation & Control Processes, Far-Eastern Branch of Russian Academy of Sciences, Vladivostok, Russia*

Received 26 December 2014; accepted 30 December 2014

Available online 25 March 2015

Abstract

A method for the determination of the deformation direction for a fibre-optic deformometer is proposed. The method is based on the two-channel scheme of a fibre-optic Mach-Zehnder interferometer.

Keywords: Interferometer; Optical fibre; Sensor; Deformation

Introduction

Development in the area of fibre optics has spurred significant growth of interest in the creation of fibre-optic measuring systems for monitoring large-scale anthropogenic objects due to the advantages of fibre-optic components. A monitoring system based on fibre-optic sensors (FOSs) has the property of physical principle clarity, which is significant from the standpoint of large-scale implementation.

In the field of monitoring the state of large-scale facilities, measurement of the parameters of strain fields is of very great interest. To solve this problem, different types of FOSs, such as amplitude sensors, fibre Bragg gratings, distributed sensors based on Brillouin and Raman scatterings, and interferometric sensors (based on Michelson or Mach-Zehnder schemes) are used [1]. Interferometric FOSs based on two-arm interferometers and requiring no additional processing of output signals seem to be the most promising from the point of view of creating deformometers with extended gage length for performing the practical tasks of monitoring large-scale facilities. However, the diversity of measurement conditions demands that the possibility be ensured of varying the deformometer sensitivity as determined by the characteristics of the fibre light guide, which cannot be substantially changed. Additionally, the high sensitivity of two-arm fibre-optic interferometers in combination with the extended gage length leads to output signal fading caused by a drift of the interferometer's working point. The indicated disadvantages substantially restrict the use of two-arm fibre-optic

* Corresponding author.

E-mail address: okamenev@mail.ru (O.T. Kamenev).

Peer review under responsibility of Far Eastern Federal University, Kangnam University, Dalian University of Technology, Kokushikan University.

http://dx.doi.org/10.1016/j.pscr.2014.12.001

1229-5450/

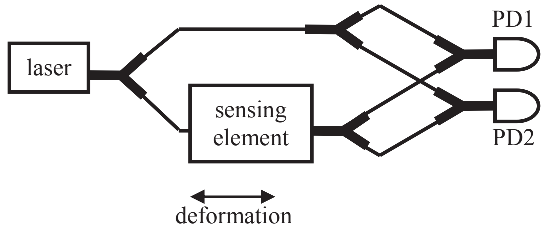

Fig. 1. Two-channel scheme of a fibre-optic Mach-Zehnder interferometer.

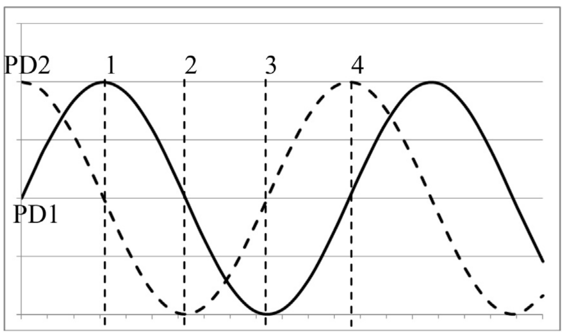

Fig. 2. Output signal of a two-channel interferometer for $\Delta\varphi = \pi/2$. PD1 – channel 1, PD2 – channel 2; 1–4 – critical points of the maximum or minimum.

interferometers in systems for monitoring large-scale facilities.

The sensing element of the deformometer based on a fibre-optic Mach-Zehnder interferometer is presented in [2]. This sensing element provides the possibility of changing the sensitivity and reducing the working point drift. However, if we use a Mach-Zehnder interferometer for long-term deformation, then there is a problem of the determination of the deformation direction at the points of the maximum and minimum interferometer output signal. This work presents a method for the solution of this problem.

Two-channel interferometer

It is possible to determine a deformation direction at all points of the interferometer transfer characteristics using the two-channel scheme of a Mach-Zehnder interferometer (Fig. 1).

Signals from photodetectors PD1 and PD2 are sinusoidal:

$$U_{PD1} = U_{01} + U_1 \sin(\beta \bullet \Delta L + \phi_{01}),$$

$$U_{PD2} = U_{02} + U_2 \sin(\beta \bullet \Delta L + \phi_{02}),$$

where ΔL is the deformation of the sensitive element fibre, β is the constant of the propagation of the fibre mode, and φ_{01} and φ_{02} are the initial phases depending on the differences between the light wave paths for channel 1 and 2, respectively. Therefore, the phase difference between signals from photodetectors PD1 and PD2 is $\Delta\phi = \phi_{01} - \phi_{02}$. The interferometer' output signals for the case of $\Delta\varphi = \pi/2$ are shown in Fig. 2.

From Fig. 2 we can see that signals from channels 1 and 2 do not reach the maximum or minimum simultaneously, so we can determine the deformations direction at any time. Because $\Delta\varphi$ does not depend on the interferometer arm length, it is more stable than the working point of the interferometer. If the output channels of the interferometer consist of identical elements, $\Delta\varphi$ has no considerable variations. Conversely, if $\Delta\varphi$ varies in the range of $\pm\frac{\pi}{4}$, the direction of deformation can be derived from the phase difference.

Experimental traces of the initial phases φ_{01} and φ_{02} and the phase shift $\Delta\varphi$ for a two-channel interferometer (free from deformations) are presented in Fig. 3.

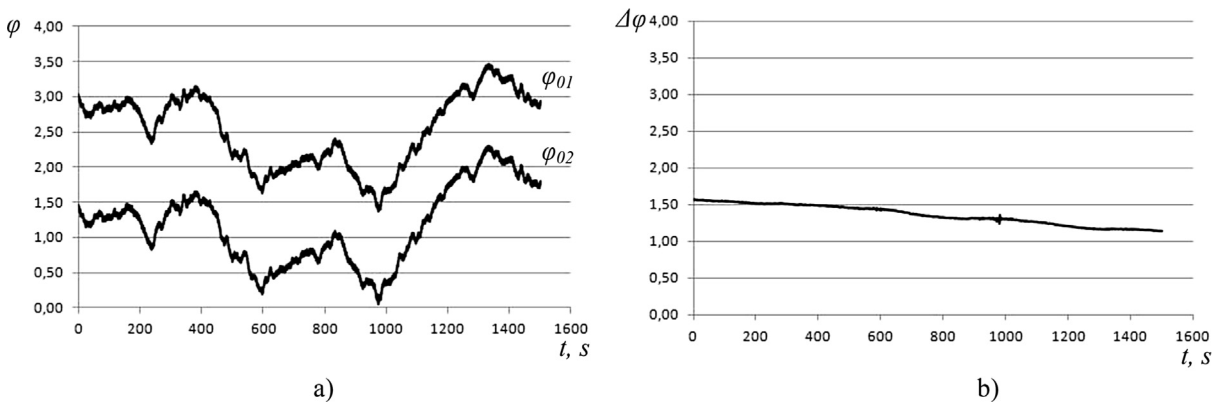

Fig. 3. Experimental time dependence of initial phases φ_{01} and φ_{02} (a) and phase shift $\Delta\varphi$ (b) for two-channel interferometer.

The variation of the initial phases is affected by the fluctuation of temperature. The phase difference between channels has only slight variation, which is much less than the variations of phases φ_{01} and φ_{02}. Therefore, stabilization of the phase difference between output signals is easier than stabilization of the interferometer working point. This stabilization can be realized using a piezoelectric modulator introduced into one of the channels.

Conclusion

In this paper, we propose a two-channel scheme for a fibre-optic Mach-Zehnder interferometer that can be used for determination of the deformation direction at the points of the maximum and minimum interferometer output signal.

Acknowledgements

The research was funded by the Russian Scientific Foundation (project #14-12-01122).

References

[1] E. Udd, Fiber Optic Smart Structures in Fiber Optic Sensors: An Introduction for Engineers and Scientists, Wiley, New York, 1991.

[2] O.T. Kamenev, YuN. Kulchin, YuS. Petrov, R.V. Khiznyak, Use of a fiber-optic Mach-Zehnder interferometer for creating a deformometer with extended gage length, Tech. Phys. Lett. 40 (2) (2014) 119–122.